Copper Cable Recycling Technology

U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology
Deactivation and Decommissioning Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

Copper Cable Recycling Technology

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U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology
Deactivation and Decommissioning
Focus Area

Demonstrated at
Idaho National Engineering and
Environmental Laboratory
Large-Scale Demonstration and
Deployment Project
Idaho Falls, Idaho

DISCLAIMER

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1
SUMMARY

Introduction

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in deactivation and decommissioning (D&D) of nuclear facilities. The Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology (OST) sponsors Large-Scale Demonstration and Deployment Projects (LSDDPs). At these LSDDPs, developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects and to others in the Deactivation and Decommissioning (D&D) community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased costs of operation.

The Idaho National Engineering and Environmental Laboratory (INEEL) LSDDP generated a list of statements defining specific needs or problems where improved technology could be incorporated into ongoing D&D tasks. A wide variety of contaminated cables are generated during deactivation and decommissioning projects at the INEEL and throughout the United States. Due to the relatively low disposal costs at the INEEL and the limited potential for the recycle of the INEEL contaminated copper cable (due to the majority of the cable at the INEEL facilities not being contaminated), the cost savings at the INEEL are expected to be less than more typical nuclear facilities within the DOE Complex.

Increasing Deactivation and Decommissioning activities of nuclear facilities generates hundreds of tons of contaminated copper cable, which are being sent to landfills for disposal. A need exists for reducing the waste volume associated with the disposal of contaminated copper cable. The Copper Cable Recycling Technology is intended to separate copper from contaminated cables, insulation and dust materials. Recovered copper can then be recycled and reused, thus reducing landfill disposal volume and conserving this valuable natural resource.

The Copper Cable Recycling Technology is applicable to facility decommissioning projects at many Department of Energy (DOE) Nuclear Facilities and Commercial Nuclear Power Plants undergoing decommissioning activities. This technology is very important during these activities, not only from a valuable resource point-of-view, but also as a means to reduce the large volumes of radioactively contaminated cables requiring permanent disposal. The existing baseline technology for disposal of radioactively contaminated cables is packaging the cables in wooden storage boxes and disposing the cables in landfills.

The LSDDP technology demonstration investigated the associated costs and time required to recycle approximately 13.5 tons of copper cable. Throughout this report the term “Copper Cable” refers to the overall or complete makeup of the cable, including the individual strands of “Copper Wire” inside, and the insulation and dust material. This should not be confused with the term “Copper Wire” which refers to the individual copper conductors which makeup the overall “Copper Cable.” The copper cable was coated with a surrogate contaminant to simulate actual contaminated cable resulting from D&D activities and to provide measurable data for evaluation purposes. The demonstration took place at the Bonneville County Technology Center located in Idaho Falls, Idaho where equipment was received and setup.

Nukem Nuclear Technologies Corporation has exclusive access to this D&D technology developed by its international affiliates; thus NUKEM provided the Copper Cable Recycling Technology for the INEEL, LSDDP. The Copper Cable Recycling Technology was developed in Stuttgart, Germany by RADOS and the Gundremmingen NPP. The RADOS Copper Cable Recycling Technology has been used in Europe to successfully recover many tons of contaminated copper cable for free release and reuse. Nukem Nuclear Technologies, a corporate affiliate of the Gundremmingen NPP is the United States Licensee of this Copper Cable Recycling Technology and is based in Columbia, South Carolina. RADOS of Stuttgart, Germany is a specialty subcontractor to NUKEM and provided the Copper Cable Recycling Technology for the Demonstration.

Technology Summary

Baseline Technology

D&D Operations at the INEEL transports all contaminated copper cable to the INEEL Remote Waste Management Complex (RWMC) landfill for disposal. This practice could be reduced or stopped if copper recycling were to become the baseline for disposition of contaminated cable. Because of the low cost for landfill disposal at the INEEL and low volume of contaminated copper cables in these surplus facilities the potential for recycle of these materials and the cost savings potential here is expected to be only moderate. However, large savings could be realized for recycling contaminated copper cables at other DOE sites.

Innovative Technology

The Copper Cable Recycling Technology provides an alternative to disposal of radioactively contaminated copper cable. This technology should be considered for all copper cable recovery projects to reduce cost, waste generation and storage. It is possible that dust and insulation granules that are waste by-products generated by the recycling process can be used as “void filler” in existing waste boxes. For example, boxes containing large diameter piping and valves, or radioactively contaminated concrete typically have large void volumes. Both the insulation and the dust could be used for this purpose assuming contamination content and levels are compatible with existing waste. Based on cost estimates obtained from local copper recycling vendors, the copper resale value is much higher when processed by the NUKEM Copper Cable Recycling Technology as opposed to non-processed copper cable.

Demonstration Summary

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. The Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology (OST) sponsors Large-Scale Demonstration and Deployment Projects (LSDDPs). At these LSDDPs, developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased costs of operation. Benefits of this technology include the ability to transport and setup the equipment in remote locations. This was demonstrated by transporting the equipment from Germany to the INEEL using two twenty-foot “sea-land“ containers. The Nukem Copper Cable Recycling Technology was then assembled and demonstrated at the Bonneville County Technology Center.

The Idaho National Engineering and Environmental Laboratory (INEEL) LSDDP generated a list of statements defining specific needs or problems where improved technology could be incorporated into ongoing D&D tasks. A wide variety of contaminated cables are generated during deactivation and decommissioning projects throughout the United States. With the increase of Decontamination and Decommissioning of nuclear facilities, hundreds of tons of contaminated copper cables are being sent to landfills. With this activity a need exists for reducing the waste volume associated with the disposal of contaminated copper cable. The Copper Cable Recycling Technology separates copper from contaminated insulation and dust. The recovered copper can then be recycled and reused, thus generating revenue and reducing the landfill disposal volume.

The benefits from this copper cable recycling demonstration include:

- Cost reduction resulting from lower storage, treatment and disposal expenses and sale of copper
- Reduction in final waste volume
- Cost reduction from the higher resale price and/or reuse of recovered clean copper
- Recovery of a valuable resource
- Handling and processing of copper granules is easier and safer than long lengths of cable
- Capability of processing many types and sizes of cable
- Proven technology
- Portability (Can be transported and setup at users facility)

Figure 1: Nukem Copper Cable Recycling Technology

Key Results

The key results of the demonstration are summarized below. Section 3 describes these results in detail.

- Reduced the overall waste volume by 80%
- The Copper Cable Recycling Technology can be set up at customer location.
- Worker fatigue was greatly reduced when using the Copper Cable Recycling Technology.
- Can provide clean copper for recycle and reuse.
- Reduces the landfill space required to dispose of the waste.
- Reduces the possibility of personal injury associated with handling large pieces of cable.
- Cost reductions and accelerated schedules are possible with large volumes of cable.

Contacts

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Cost Analysis

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Web Site

The INEEL LSDDP Internet web site address is http://id.inel.gov/lsddp

Licensing

Nukem Nuclear Technologies is the exclusive United States Licensee of this Copper Cable Recycling Technology and is based in Columbia, South Carolina. RADOS of Stuttgart, Germany is a specialty subcontractor to NUKEM and provided the Copper Cable Recycling Technology for the Demonstration.

Permitting

No permitting activities were required to support this demonstration other than a Job Safety Analysis (JSA), however, the treatment of contaminated cable at an existing nuclear facility would require confirmation that the operation of the process can be performed within the existing safety basis of the facility

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under “Publications”. The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for the NUKEM Copper Cable Recycling Technology is 2958.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Thirteen and one-half tons of copper cable was available at the demonstration site for recycling. The total was divided into two parts to allow demonstrations using non-contaminated cable and demonstrations using surrogate contaminated cable. This sizing and segregating process was completed prior to receipt of the Nukem equipment. The unit was capable of processing up to a maximum of six tons of insulated copper cable per day, ranging from small individual strands of wire up to large (two inches in diameter) power cables, in random lengths or coils

All activities and operations taking place during the demonstration of the surrogate contaminated wire/cable were treated as if it were radiologically contaminated including generation of appropriate documents, personal protection equipment (PPE), monitoring, environmental and air controls. All personnel associated with operations of the equipment were assumed to be radiation worker trained to the level commensurate with the radiation levels typically experienced.

A pre-job and post-job debriefing was conducted to collect observations, concerns, and opinions of operators, sampling personnel, industrial and safety personnel, and other support personnel.

Demonstration Goals and Objectives

This field demonstration of the NUKEM Copper Cable Recycling Technology is part of a larger series of demonstrations executed under the Large Scale Demonstration and Deployment Project (LSDDP) funded by the Department of Energy (DOE) Office of Science and Technology (OST). The primary purpose of the LSDDP is to demonstrate innovative technologies on a large-scale basis in conjunction with Decontamination and Decommissioning (D&D) activities. The innovative technologies demonstrated are compared against DOE's baselines and/or industrial baseline technologies in the relevant areas.

The scope of this project was to demonstrate the NUKEM Copper Cable Recycling technology for processing and recycling of radioactively contaminated and non-radioactively contaminated copper cable at the Idaho National Engineering and Environmental Laboratory (INEEL). This demonstration was performed as part of the INEEL Large Scale Demonstration and Deployment Project (LSDDP). The NUKEM process was evaluated for efficiency, reliability and potential for cost and schedule savings compared to the current baseline at the INEEL.

The first objective of the LSDDP is to identify existing technologies unproven in D&D applications that address the defined problems or needs of DOE D&D activities. The second objective is to quantify and document the benefits that can be realized from a side by side comparison of the innovative and baseline technologies. Possible benefits include reduced cost, reduced exposure, increased safety, and ease of application and reduced schedule. This direct comparison provides an opportunity to assess the impact of the innovative technology against the baseline and validate the benefits to be gained.

The purpose of this field demonstration was to assess the effectiveness of the NUKEM Copper Cable Recycling Technology in separating uncontaminated copper from its contaminated insulation and providing separate output streams for uncontaminated copper, contaminated insulation and contaminated dust products. This demonstration provided sufficient data to develop a cost benefit analysis for fair and independent comparison of the potential benefits of the NUKEM Copper Cable Recycling Technology over baseline technologies at end-user sites. These benefits can be re-evaluated by the end-user based on the changing value of copper and changing costs of alternative disposal methods.

High volumes of uncontaminated copper were collected by the Copper Cable Recycling Technology, which demonstrated that contaminated insulation material can be successfully separated from the uncontaminated copper wire so the non-contaminated copper can be recycled or reused. Data was collected for surrogate contaminated cable and non-contaminated cable using 55-gallon drums as the collection containers for the copper.

Figure 2: Excess Copper Cable

Description of the Technology

The NUKEM Copper Cable Recycling Technology was transported to the INEEL where it was setup to recycle non-radioactively contaminated cable as well as cable with a surrogate contaminate applied. The Copper Cable Recycling Technology processed approximately 13.5 (US) tons of insulated/coated copper cable. Data was collected during training, setup, operations, maintenance, decontamination, and demobilization activities. Granulated copper and surrogate contaminated cable insulation and dust materials were collected in 55-gallon drums or plywood waste boxes.

The processed cable was separated into contaminated and non-contaminated material fractions in an air-separation chamber. The contaminated portion is the outer covering or cable insulation and dust materials associated with the inner fillers and strength fibers used in the makeup of multi-conductor cables. The non-contaminated portion (which is the copper wire) is recovered from the inside of the insulation/covering. The relatively lighter insulation and dust granules float on a layer of air above the sieve, while the heavier copper fraction is separated by control of the sieve. Obtaining high volumes of uncontaminated copper for recycling and high volumes of materials that can be used as void fillers in low-level radioactive waste containers was one of the objectives of the technology demonstration.

Contaminated dust generated by the grinding process is filtered through a three-stage process to prevent the release of airborne contamination. A special design inherent to the NUKEM Copper Cable Recycling Technology prevents the rebinding of contaminated dust to the insulation material. The dust filters and the off-gas filter are encapsulated and monitored for particulate buildup and cleaned or replaced as required. The dust filters did not require replacement or cleaning during the processing of 13.5 tons of cable. Larger amounts however, would require changing the filters and this frequency would depend on the amount and types of cables being processed.

System Operation

The cables were placed on the conveyor to feed into a pre-shredder (cables can be fed as rings or as short pieces). The larger cables were cut into approximate 30-inch lengths to facilitate ease of handling and provide a constant feed into the Copper Cable Recycling Technology. The speed at which the cables were fed into Copper Cable Recycling Technology was determined by the amperage draw of the shredder/grinder motors. An amperage meter located on the side of the conveyor was observed continually by the operators during the process to regulate their feed rate. If the current exceeded the system limit, it was necessary to reduce or stop

Figure 3: Placing Cables on Conveyor

the feed until the amperage lowered back within the operating range.

The grinder is a horizontal shaft with grinding blades placed on the circumference of the shaft. The grinder granulates the copper wire, filler/strengthening fibers and the insulation material covering the copper wire. During the grinding process, most of the contamination is removed from the insulation due to strong mechanical sheer tension in the grinder.

The NUKEM Copper Cable Recycling Technology Operational Procedure was reviewed by all personnel involved in the setup and operation of the equipment. NUKEM personnel held a review with the INEEL and Bonneville County Technology Center (BCTC) personnel and covered each step of the procedure as required during the pre-job briefings. These operational steps were followed during setup, operation and disassembly of the equipment. Personnel were briefed with the procedure and followed all safety guidelines established in the INEEL Job Safety Analysis (JSA).

Table 1 summarizes the operational parameters and conditions of the Copper Cable Recycling Demonstration.

Table 1. Operational parameters and conditions of the Copper Cable Recycling Demonstration

Working Conditions	
Work area location	Bonneville County Technology Center, Idaho Falls, ID
Work area access	Public access with restrictions to equipment operational areas
Work area description	Work area restricted and controlled due to noise and safety requirements, requiring training, safety glasses, and ear protection for entry. Under certain conditions, respirators and anti-C clothing were required.
Work area hazards	Noise hazards Surrogate contamination (Cesium and Cobalt nitrate) Tripping hazards Lifting and cutting cable Forklift operation
Equipment configuration	Two portable Sea-Land Containers stacked, one on top of the other
Labor, Support Personnel, Special Skills, Training	
Work crew	Minimum work crew: • 1 Forklift operator • 2 Nukem equipment operators • 2 Laborers
Additional support personnel	• 1 Data Collector • 1 Health and Safety Observer (periodic) • 1 Test Engineer
Special skills/training	Review and briefing of operation manual. Skill was required to maintain feed rate into conveyor. Operator training, skill and experience are required for setup and operation of NUKEM equipment.
Waste Management	
Primary waste generated	No primary wastes were generated other than the insulation and dust material.
Secondary waste generated	Disposable of miscellaneous waste was through the Bonneville County landfill. Personal Protective Clothing
Waste containment and disposal	The copper was returned to the INEEL excess area at CFA. The insulation and dust material was taken to the INEEL landfill.
Equipment Specifications and Operational Parameters	
Technology design purpose	Equipment is designed to grind the wire and separate it into three output streams; copper, insulation and dust material.
Portability	Equipment can be packaged and transported to recycling site.
Materials Used	
Work area preparation	No facility preparation was necessary for the demonstration. HEPA filters were obtained and setup Cobalt, Cesium Nitrate and Phosphorescent Powder was used for surrogate contamination on the cable 55 gal. Drums were staged for the copper recovery 2x4x8 ft. wooded boxes were staged for the insulation and dust recovery.
Personal protective equipment	Hearing protection Cotton glove liners (When applicable) Tyvek coveralls (When applicable) Respirators (When applicable) Pair of rubber gloves (When applicable) Shoe covers (When applicable) Steel toe shoes, Safety glasses, Leather Gloves
Utilities/Energy Requirements	
Power, fuel, etc.	Diesel fuel for 150kW generator Gasoline for forklift

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

Although the INEEL has very little radiologically contaminated cable, commercial industry has large volumes that are contaminated. For this reason there is a high level of interest in how effective this technology performs with radioactively contaminated cable. For demonstration of contaminated cable, the cable was treated with surrogate contamination that presented all the challenges and activities that would be encountered with actual radiological contamination but without the associated hazards. At the conclusion of the demonstration a black light was used to examine the HEPA filters as well as the area around the filters to determine the effectiveness of the system in separating the phosphorescent powder (which was applied to some the cable) from the copper. No phosphorescent powder was found in the HEPA filters or in the area of the filter housings. Some phosphorescent powder was found in the pre-filters and on the conveyor and parts where the cable came in contact during the feed process into the Copper Cable Recycling Technology.

This demonstration provided field data regarding processing and recycling, by use of surrogate contamination and non-contaminated copper cable at the Idaho National Engineering and Environmental Laboratory (INEEL). One benefit of Copper Cable Recycling Technology is the reduction of radioactive waste requiring permanent disposal and the recycling of copper for future use. The baseline technology is to remove contaminated cable from a facility being decommissioned, size and package cables in waste storage boxes or soft-sided containers, and transporting it to the Radioactive Waste Management Complex for disposal as low-level waste. The baseline process for non-contaminated cable includes removal or "rip-out" of the cable from decommissioned facilities, loading the cables into a dump truck, and transporting it to the INEEL Central Facilities Area (CFA) Excess Yard where it is sold as scrap.

Demonstration site description

The INEEL site occupies 569,135 acres (889 square miles) in southeast Idaho. The site consists of several primary facility areas situated on an expanse of otherwise undeveloped, high-desert terrain. Buildings and structures at the INEEL are clustered within these primary facility areas, which are typically less than a few square miles in size and separated from each other by miles of primarily undeveloped land.

The NUKEM Copper Cable Recycling Technology was received at the Bonneville County Technology Center located in Idaho Falls. A concrete pad was made available with a 50 ft. x 50 ft. footprint for the Copper Cable Recycling Technology, a staging area for the cable, a staging area for filled drums, and an area for vehicle/equipment access. The Copper Cable Recycling Technology was assembled on the East Side of the BCTC on a concrete pad approximately 50 ft. from the building. The high bay area was used for staging the cable, drums and all associated equipment. This area remained accessible during the recycling demonstration to allow moving the cable and processed materials into and out of the facility.

Major objectives of the demonstration

The first objective of the LSDDP was to identify existing technologies unproven in D&D applications that address the defined problems or needs of DOE D&D activities. The second objective is to quantify and document the benefits that can be realized from recovery of copper and the reduction of waste going to landfills for disposal. Possible benefits include reduced cost, reduced exposure, increased safety, and ease of application and reduced schedule. This direct comparison provides an opportunity to assess the impact of the innovative technology against the baseline and validate the benefits to be gained.

Major elements of the demonstration

This demonstration provided field data regarding processing and recycling, by use of surrogate contamination and non-contaminated copper cable at the Idaho National Engineering and Environmental Laboratory (INEEL).

The major elements of this demonstration were 1) the setup of the equipment, 2) preparation of the surrogate contaminated and uncontaminated cable, 3) operation of the NUKEM Recycle equipment, 4) demobilization, and 5) assessment of the results.

Results

The Copper Cable Recycling Technology operated very well over a period of approximately five days. Twenty-one 2”x4’x8’ waste boxes containing 27,100 pounds of copper cable were processed during the demonstration. The demonstration generated 9.5 55-gallon drums of clean copper (17,250 lbs.), five 2’x4’x8’ waste boxes of granular insulation and four 2’x4’x8’ waste boxes of dust.

During this demonstration work was performed in 10-hour shifts. Assuming 8 hours of productive time, we had a maximum throughput of 1,500 lbs. per hour. An average throughput during the entire demonstration was 847 lbs. per hour, assuming 32 hours of operation time. This included the time required for setting up the equipment at the beginning of the day and shutting down and cleanup at the end of the day. The overall run-time for the demonstration was 32 hours, which included the time required each day for setup and shutdown of the

Figure 4: Clean Copper - Ready For Reuse

equipment. This is the time used in the cost analysis (section 5) for actual run-time and was used for calculating the average of 847 lbs/hr for the entire demonstration. Each time the Copper Cable Recycling Technology is shut down and restarted, approximately 2 hours is required to balance the air movers at the beginning of the day and to allow the copper to clean out of the system at the end of the day. This may vary but needs to be considered each time the Copper Cable Recycling Technology is started and stopped.

The individual wire strands or conductors were in the form of stranded and solid wire, bare and insulated and 20 gauge (0.0348-inch diameter) up to 4-0 gauge (0.3938-inch diameter. Cables with a diameter of 1.2 inches or greater must be no longer than 30 inches. An overall insulated cable may contain multiple insulated inner conductors or wires.

The demonstration collected valid operational data so that legitimate comparison can be made between the innovative technology and the baseline technology in the following areas:

- Safety
- Productivity rates
- Ease of use
- Limitations and benefits
- Cost

SIMULATION REPORT

The Simulant

One of the surrogates used to simulate loose contamination was a phosphorescent powder. This was applied to the surface of the wire prior to processing. During processing, samples of copper, insulation and dust were collected and examined with a black light. The results showed no phosphorescent powder in the processed copper wire or the insulation granules. A small amount of phosphorescent powder was detected in the dust samples, however this was expected. After the processing the entire system was examined using a black light. Phosphorescent powder was found on the conveyor, on the entrance to the pre-shedder, the first stage of dust absorbers and in the dust filter bags, all of which were expected. The results obtained using the phosphorescent powder to simulate loose contamination, the copper cable recycling system is capable of separating the copper from the simulated contamination applied to the cables insulation or outer covering.

The simulation of contaminated cable was used to allow the demonstration to be conducted offsite and to illuminate the risk of contaminating the equipment to the extent it could not be returned to NUKEM. A simulant was used that would simulate radioactive contamination on the copper cable that was to be recycled. Cesium nitrate was chosen as a non-radioactive chemical. This was chosen to mimic the radioactive cesium 134 and 137 isotopes that are frequently seen at INTEC (Idaho Nuclear Technology and Engineering Center). Cobalt nitrate was also used in conjunction with cesium nitrate in a separate batch of cable. Both batches acted similar to the radioactive isotopes of the same chemicals.

The simulant was applied to copper cable using a commercially available hand pressurized sprayer. The spray was restricted to the center of the cable length, leaving six inches of each end without simulant. The first batch of cable was placed on wooden pallets with plastic underneath. The first batch of simulant was the cesium and cobalt mixture. A second batch of “contaminated” cable was made using cesium simulant only. The simulant was allowed to air dry on the cable and then placed back in the 2’X4’X8’ wooden box for processing. The simulant was fixed by applying latex paint over the already applied simulant on the cable. A similar hand pressurized sprayer was used to apply the paint. Of the 27,100 lbs. of cable, approximately 15,000 lbs. were treated with a surrogate contamination.

The individual wire strands or conductors were in the form of stranded and solid wire, bare and insulated and 20 gauge (0.0348-inch diameter) up to 4-0 gauge (0.3938-inch diameter. Copper cables with a diameter of 1.2 inches or greater must be no longer than 30 inches. An overall insulated cable may contain multiple insulated inner conductors or wires. The cable was a mixture of sizes and insulation types. Each cable was separated by wire size (about 0.5 mm.[small], 1 mm.[medium], and 2 mm.[large]) into wooden boxes (2'X4'X8'). The cable varied from single strands of wire to large 2-½ inch cables with 5 conductors of multiple small wires. Many of the cables had a very thin copper shield under the outer insulation with a center of multiple large strands of copper wire.

The Sampling

The sampling of the copper and insulation was directly into a 125 ml or 30 ml plastic bottle from the processed copper (see figure 5) and insulation (see figure 6) streams as they flowed into the 55 gallon drums. The dust was sampled by removing it from the dust collection bags and placing it into 125-ml bottles. Gloves were changed for each sampling. All bottles were labeled as to item sampled and date and time taken. Samples were recorded in the log book “LN-589”. All samples were then transported to INTEC for preparation and analysis.

The Analysis

Chemical analysis was performed on the samples after leaching fifty milliliters of sample with seventy milliliters of high purity water. The leachate was filtered, labeled, and sent to analytical chemistry for analysis. The cesium was analyzed by atomic absorbtion (AA) and the cobalt was analyzed by inductively coupled plasma (ICP). The concentration of the cold chemical was at a higher level of concentration than would be needed if it were radioactive. This is due to the difference in measuring radioactivity. The ability to detect radioactivity at low concentration is very sensitivity, when compared to detection of the actual metal concentration. The higher concentration of cold simulant was used so sufficient analyte would be present in the product to determine the decontamination reduction. For example, if there were zero contamination coming through the process, it would be difficult to know if the process were working. An amount is necessary to determine the level at which the process will operate.

Table 2 : The Simulant Analysis

Results from Copper Cable Recycling Project

Sample Name	Date & Time	WireSize	Cs Decon Factor w/cable adjustment	Cesium Results ug/mL	ug Cs per g Cu
Cesium Simulant				**39700**	37.54
BC-1	11/15/99 ~1600	Small		≥0.004	>0.0015
BC-2	11/15/99 ~1600	Large		≥0.004	>0.0011
C-1	11/17/99 0816	Large	251.20	0.538	0.1494
C-2	11/17/99 0835	Large	274.13	0.493	0.1369
C-3	11/17/99 0855	Large	402.21	0.336	0.0933
C-4	11/17/99 0920	Large	325.65	0.415	0.1153
C-5	11/17/99 0935	Large	256.44	0.527	0.1464
C-6	11/17/99 0950	Large	193.89	0.697	0.1936
C-7	11/17/99 1005	Large	143.77	0.940	0.2611
C-8	11/17/99 1020	Large	168.51	0.802	0.2228
C-9	11/17/99 1035	Large	184.62	0.732	0.2033
C-10	11/17/99 1050	Large	224.49	0.602	0.1672
C-11	11/17/99 1101	Large	206.01	0.656	0.1822
C-12	11/17/99 1129	Medium	841.72	0.128	0.0446
C-13	11/17/99 1144	Small	172.81	0.562	0.2172
C-14	11/17/99 1207	Small	2477.59	0.039	0.0152
C-15	11/17/99 1222	Small	6744.54	0.014	0.0056
C-16	11/17/99 1237	Small	5006.25	0.019	0.0075
C-17	11/17/99 1252	Small	6652.15	0.015	0.0056
C-18	11/17/99 1307	Small	4905.12	0.020	0.0077
C-19	11/17/99 1322	Small	3706.92	0.026	0.0101
C-20	11/17/99 1337	Small	2728.13	0.036	0.0138

Chemical analysis was performed on the samples after leaching fifty milliliters of sample with seventy milliliters of high purity water (type I). The leachate was filtered, labeled, and sent to analytical chemistry for analysis. Cesium was analyzed by atomic absorption (AA) and cobalt was analyzed by inductively coupled plasma.

The Decon Factor Calculation

The decontamination factor was determined by calculating the relative reduction in concentration from the simulant on the cable to the final concentration in the processed copper. Similar cable was process in the laboratory to determine the amount of simulant actually on the cable. These values gave the initial concentration of simulant on the cable in ug/g of copper. The processed sample results (final concentration) were then calculated as concentration of simulant per gram of copper. The two values were then divided to give decontamination factor (i.e. decontamination factor equals initial concentration divided by final concentration).

$$DF = IC / PC$$

IC is the initial concentration
PC is the final concentration
DF is the decontamination factor

Conclusion

The simulant gave reliable decontamination factors that can be used as a reference to determine the decontamination of copper cable. The data shows that the Copper Cable Recycling Technology works well. Decontamination factors of 143 to 6744 were achieved depending on the cable used with the cesium nitrate simulant. Very similar results were shown with the cobalt nitrate and cesium nitrate combination simulant. The larger the copper wires in the cable the harder (slower) it was to process. The decontamination factors followed this trend. The smallest copper wire in the cable gave the highest decontamination factor. This makes sense since it is mechanically easier to process the smaller wire (cut, size, separate, and move). The data is only representative of cesium, however, assumptions are that other radionuclides would have similar decontamination factors if they chemically and mechanically behave as cesium does.

Figure 5: Copper Granules 1

Figure 6: Insulation Granules 1

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline technology

The goal is to reduce the amount of waste going to Low Level Waste and Sanitary Landfill disposal sites and to increase the amount of material recycled or reused. This will significantly reduce the overall cost of D&D projects and the waste of our natural resources.

Other competing technologies

Decon and Recovery Services of Oak Ridge, LLC
PO Box 5298
Oak Ridge, TN. 37831
(423) 241-0638 Contact: Lance Escue

Technology Applicability

Opportunity to recycle or reuse copper cables from facility decommissioning would result in significant reductions in the volume of waste requiring disposal. Many wastes are generated in the process of decommissioning a contaminated nuclear facility. Typically, large amounts of copper cable are encountered as waste and require immediate disposal actions.

Huge volumes of copper cable wastes are generated during the decommissioning of a typical nuclear facility. Part of these wastes are radioactively contaminated and are disposed of at Low Level Waste disposal sites such as the INEEL's Radioactive Waste Management Complex. The remainder of the waste from a D&D project is not contaminated and is typically disposed of at a conventional Sanitary Landfill. Very little D&D waste is typically recycled or reused. Thus, not only do huge amounts of radioactive and non contaminated material end up in disposal facilities, but the recycle potential for these materials is lost. The consequences of not filling this need are the continued high cost of disposing of D&D wastes and of the wasting of our natural resources. Because of the very high volumes of waste associated with the decommissioning of nuclear facilities these activities have a very negative impact on disposal facilities. This is particularly true of Low-Level Waste disposal sites. This often causes pressure and negative reaction to the decommissioning of these surplus facilities. The Copper Cable Recycling Technology would have immediate application at DOE sites where facility D&D is planned or underway. These sites include the INEEL, Mound and the Oak Ridge, East Tennessee Technology Park (ETTP) Project.

Although the INEEL has very little radiologically contaminated wire/cable, the commercial industry has a very high percentage that is contaminated. For this reason there is a high level of interest in how effective this technology performs with radioactively contaminated wire/cable. It has potential to reduce costs for many D&D projects through the United Sates.

Patents/Commercialization/Sponsor

Nukem Nuclear Technologies is the exclusive United States Licensee of this Copper Cable Recycling Technology and is based in Columbia, South Carolina. RADOS of Stuttgart, Germany is a specialty subcontractor to NUKEM and provided the Copper Cable Recycling Technology for the Demonstration.

SECTION 5
COST

Introduction

This section compares the disposition of copper cable for the innovative and the baseline technologies. The innovative technology and the baseline technology costs are approximately equal for a job where 25,000 pounds of copper cable are processed. Larger quantities of cable will increase the cost effectiveness of the Copper Cable Recycling Technology. This comparison includes the credit for recycling the copper material.

Methodology

This analysis is based on the innovative technology being a vendor–provided service to the Government, as opposed to Government purchase or rental of the equipment. Accordingly, the majority of labor involved in the innovative technology is assumed to be vendor-provided, as opposed to INEEL provided. The observed activities for the case of the innovative technology include mobilization, set-up, and demobilization, and disposal. In the demonstration, a crew of INEEL laborers segmented the cable in an activity that was separate to feeding the cables into the NUKEM equipment. But, in past jobs using the NUKEM Copper Cable Recycling Technology, the cable was segmented as it was fed into the NUKEM equipment. It is assumed in this cost analysis, that segmenting is not a separate activity and that the NUKEM operators and one INEEL laborer would segment the cable as part of the feed process. The INEEL laborer would have two duties, helping segment the cables and operating the forklift. Disposal of 4 boxes of dust is assumed in the cost analysis. However, it is possible the dust material be further compacted or used as void filler reducing the waste volume even lower. The innovative technology generated 5 boxes of insulation material waste that is assumed to be useful as a void filling material. Consequently; disposal costs for the 5 boxes of insulation are not included in this analysis. The mobilization of the innovative technology includes airfare, per-diem, car rental, shipping for the equipment, and the INEEL procurement costs for the equipment. Demobilization includes decontamination of the equipment prior to leaving INEEL. The D&D work costs include donning and doffing PPE, machine processing, sales of the recycled product, and laboratory analysis. The crew for the demonstration of the Copper Cable Recycling Technology includes 4 process operators for the NUKEM equipment and 1 forklift operator/laborer. It is assumed that the INEEL site provides the forklift operator. This composite crew is believed to be typical of any crew used for the operation of the NUKEM Copper Cable Recycling Technology. The demonstration of the innovative technology was performed in an uncontaminated area with uncontaminated cable. The costs were adjusted for contaminated work by assuming costs for donning and doffing PPE and decontamination of the equipment.

The costs for the baseline technology include transporting 21 boxes of waste cable to the disposal area and the disposal charges.

The labor rates for the INEEL-furnished crewmembers and equipment are based on standard rates for the INEEL site. There were some productivity losses associated with the use of the baseline and innovative technologies. Additional details of the basis of the cost analysis are described in Appendix B.

Cost Analysis

Costs to Procure NUKEM Copper Cable Recycling Technology

At this time, the NUKEM Copper Cable Recycling Technology is available from the vendor only as a vendor-provided service, i.e., only as a service by NUKEM, with no purchase or rental options. The most recent per-day quoted price is $14,500 and includes equipment and operators. The detail costs of the equipment used in this demonstration are shown in Table 3.

Table 3. Innovative Technology Costs

Acquisition Option	Item Description	Cost/Day
Vendor-Provided Service	NUKEM Cable Stripper System	$14,500 [1]

[1] Costs per NUKEM Nuclear Technologies, Corporation, January 25, 2000.

Unit Costs and Fixed Costs

Table 4 shows the unit costs and fixed costs for the innovative and baseline technologies. These costs are based on a job size of 27,100 pounds of cable and they are summarized in Appendix B, Tables B-2 and B-3.

Table 4. Summary of Costs and Production rates

COST ELEMENT	INNOVATIVE COST	PRODUCTION RATE	BASELINE COST	PRODUCTION RATE
Mobilization	$47,200 each	N/A	N/A	N/A
D&D Work	$2.23/lb	847 lb/hr	N/A	N/A
Demobilization	$33,267 each	N/A	N/A	N/A
Waste Disposal	$150/cf of dust	N/A	$150/cf of cable	N/A

The innovative D&D work costs include the cost to process the wire and the costs for laboratory analysis of samples collected during the processing. (See Appendix B, Table B-2, for the baseline technology costs). The innovative technology costs are for a vendor-provided service and equipment. (See Appendix B, Table B-3, for the innovative technology costs).

Break-Even Point

A large portion of the innovative technology's costs is mobilization and demobilization costs, which remain relatively the same irrespective of the quantity of cable processed. Consequently, the innovative technology compares differently with the baseline technology for different size jobs. Figure 7 shows that for jobs that are larger than 25,000 lbs of cable, the innovative technology will be more cost effective than the baseline technology.

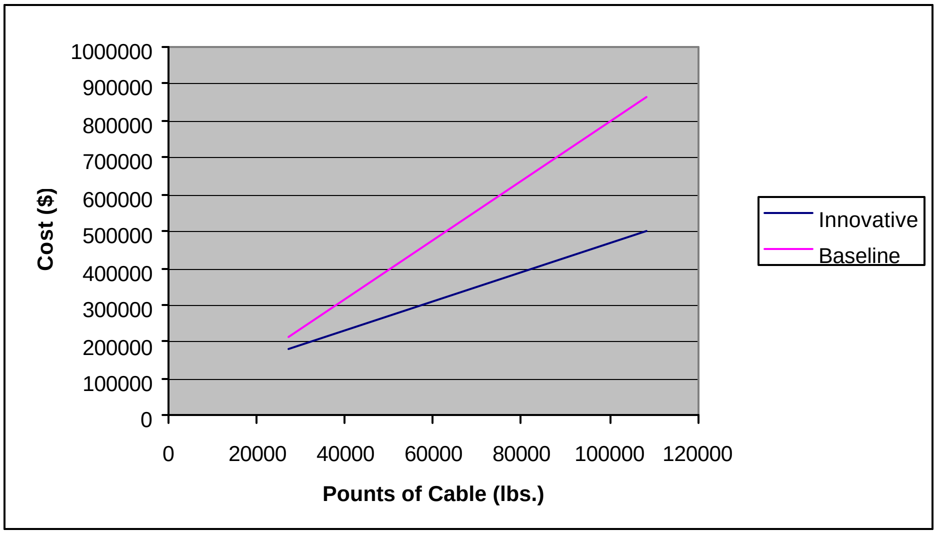

Figure 7 Job Cost as a Function of Job Size

Pay-Back Analyses

The innovative technology is currently available only as a vendor provided service. As a vendor provided service, there are no capital costs to recover.

Observed Costs for Demonstration

Figure 7 summarizes the observed costs for the innovative and baseline technology based on a job size of 27,100 pounds. The details of these costs are shown in Appendix B and includes Tables B-2 and B-3 which can be used to compute site-specific cost by adjusting for different labor rates, crew makeup, etc.

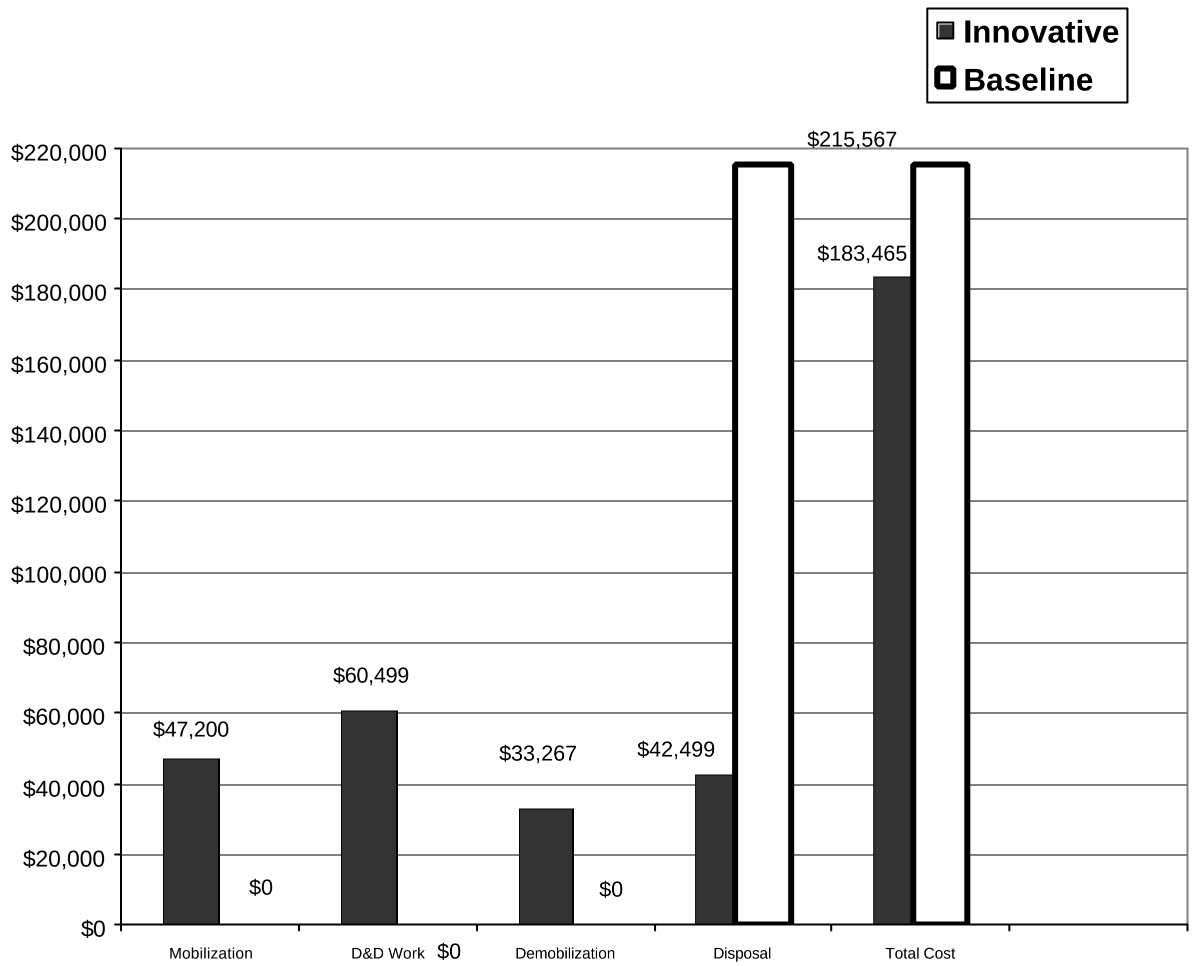

Figure 8. Summary of Technology Costs

Figure 9. Before and After Processing

Cost Conclusions

Mobilizing and demobilizing the innovative equipment is a substantial cost and, in this demonstration, are approximately 40% of the total cost for this size job. For jobs that are smaller than this demonstration the baseline method (disposal) is less expensive than the innovative technology. Jobs that are larger than this demonstration may have significantly more cost savings for the innovative technology. (see figure 7 for costs as a function of job size). Future jobs should require less time to setup the HEPA filtration system. The HEPA filter setup for this demonstration required several days, due to HEPA equipment sizing and availability problems, however, 4 hours are assumed in this cost analysis as being typical of future work. Coordination of the HEPA filter requirements for the NUKEM Copper Cable Recycling Technology is a critical factor in minimizing the setup time. The hookup to power is anticipated to be easier in future jobs. The model demonstrated is not able to run off of the site's electrical grid, and a generator and special electrical hookup were required. Future models are anticipated to run on congenital power. Future use on contaminated cable would require implementation of contamination controls and release surveys including transportation authorizations pursuant to 49 CFR.

Figure 10. Staged Copper Cable

The production rates observed in this demonstration are for non-radioactive contaminated work areas. NUKEM's experience with decommissioning at commercial nuclear facilities is a mix of working conditions. Some conditions require wearing respirators and other situations do not. If wearing respirators is required, then the overall production would be reduced and costs would be higher than as reported in this cost analysis.

For the majority of the demonstration, the workers in this demonstration did not wear a respirator or anti-contamination clothing The cost analysis includes daily costs for PPE but does not include respirators, cartridges, additional breaks for heat and fatigue, loss of dexterity and productivity because of respirators. If respiratory protection and the typical PPE were worn, it may have reduced the production rate by an additional 25% - 50% because of more frequent work breaks, heat stress, dexterity loss, etc. The respiratory protection loss factors are from the Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates, Atomic Industrial Forum, Inc., May 1986. The additional costs of work associated with working in contaminated areas may make the baseline technology more cost effective than the innovative technology in some case.

Disposal costs at INEEL are assumed to be $150 per cubic foot of waste based on historic costs observed at INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging the waste, closure of the disposal facility, or long term maintenance and surveillance. The cost comparison is sensitive to the disposal cost. Sites that have lower disposal costs would favor the baseline technology and sites with higher disposal costs would favor the innovative technology.

Cost savings potential comes from two areas. The first is from the reduced volume of waste going to disposal facilities. In this area, savings are realized from decreased packaging and transportation costs and from extending the lives of the disposal facilities. The second area having cost savings potential is in the reuse or recycle of the copper. These are natural resource materials and their recycle ultimately represents a cost saving to the country. Because of the size and nature of INEEL surplus facilities and the potential for recycle of these materials, the cost savings potential here is expected to be only moderate. However, on a DOE complex wide basis extremely large cost savings could be realized.

Figure 11: Dust Particulate

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

The NUKEM Copper Cable Recycling Technology meets the Department of Transportation requirements for 49 CFR, however, for this demonstration there was no radioactive contamination involved and therefore was released clean from the INEEL. The INEEL did not require receipt inspection for radioactive contamination as the equipment was received off-site and was surveyed below allowable limits prior to shipment from Germany. Because the equipment was not demonstrated on the INEEL boundaries, no survey was required to release the equipment prior to shipment back to Germany. The cable that was processed was surveyed 100% to assure there was no contamination released off-site. For this demonstration, a Test Plan, Operational Procedure and Job Safety Analysis covered the use of the NUKEM Copper Cable Recycling Technology under the INEEL LSDDP.

Safety, Risks, Benefits, and Community Reaction

The safety issues associated with the use of the NUKEM Copper Cable Recycling Technology is primarily noise levels and radioactive contamination hazards. The noise risk is mitigated by the use of proper hearing protection and monitoring equipment. The radioactive contamination hazard is mitigated by the proper use of personal protective equipment, the use of HEPA filtration systems and the use continuous air monitoring equipment. The risks associated with the use of the NUKEM Copper Cable Recycling Technology are acceptable, however the allowable release limits of the recycled copper to the public is specific to each individual site with state and federal oversight.

See below for additional noise monitoring data.

Industrial Safety Noise Monitoring

Industrial Hygiene (IH) performed noise monitoring, per MCP-153, relating to NUKEM Copper Cable Recycling Technology. Monitoring is necessary to (1) determine workplace noise levels, (2) ensure adequate controls have been implemented, and (3) ensure compliance with applicable standards.

A description of the task and specific details associated with the monitoring events, follow:

Personal noise monitoring was performed during normal operation of the NUKEM Copper Cable Recycling Technology.

Personal protective equipment (PPE) used by this employee was:

- Blue Coveralls
- Eye/Face Safety Protection
- Leather Gloves
- Hearing Muffs

Personal monitoring results were:

- Sample #1
  Sample Date: 11/18/1999
  Peak Level: 115.6 DBA
  Exposure Limit: 84.5 DBA/9HOUR
  Time Weighted Average (TWA) Exposure Level: 87.2 DBA
  Comments: LABORER
  MONITORING TIME WAS 8:28

- Sample #2
  Sample Date: 11/18/1999
  Peak Level: 96.5 DBA
  Exposure Limit: 84.5 DBA/9HOUR
  TWA Exposure Level: 76.7 DBA
  Comments: LABORER
  MONITORING TIME 8:35

- Sample #3
  Sample Date: 11/18/1999
  Peak Level: 111.2 DBA
  Exposure Limit: 84.5 DBA/9HOUR
  TWA Exposure Level: 96.5 DBA
  Comments: OPERATOR
  MONITORING TIME 8:29

Area monitoring was performed to document sound levels associated with the operation of the NUKEM Copper Cable Recycling Technology.

Area monitoring results were:

- Sample #:4

Sound Level: 84.0 DBA
Sample Date: 11/16/1999
Exposure Limit: 85.0 DBA/8HOUR
Comments: NEAR OPERATOR’S EAR, WHILE LOADING CONVEYER BELT

- Sample #:5
  Sound Level: 82.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: NEAR OPERATOR'S EAR, WHILE LOADING CONVEYER BELT

- Sample #:6
  Sound Level: 79.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: APPROXIMATELY 10 FEET FROM CONVEYER BELT

- Sample #:7
  Sound Level: 92.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: OUTSIDE NEAR GRINDER EXHAUST SYSTEM

- Sample #:8
  Sound Level: 87.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: OUTSIDE NEAR SEPARATOR EXHAUST SYSTEM

- Sample #:9
  Sound Level: 106.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: INSIDE BETWEEN SEPARATOR AND GRINDER

- Sample #:10
  Sound Level: 103.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: INSIDE NEAR CONTROL PANEL

- Sample #:11
  Sound Level: 96.0 DBA
  Sample Date: 11/17/1999
  Exposure Limit: 85.0 DBA/8HOUR
  Comments: INSIDE UPSTAIRS

The exposure limit represents the noise level under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse health effects. Although some high noise levels were recorded, the employee's average exposure was well below the limit. In this instance, the employee was adequately protected with the controls in place. However, because of the potential for noise exposures above the limit, employees associated with future operations of this equipment should be required to wear hearing protection devices.

SECTION 7
LESSONS LEARNED

Implementation Considerations

Two options may be considered for implementation of this technology. Option one is setting up the technology at NUKEM's facility and shipping the copper cable to NUKEM for recycling. The second option is for NUKEM to develop a portable unit, which could be easily deployed at the customer's location. There are advantages and disadvantages to both options and each customer should consider which option would provide the most cost-effective results for their recycling needs. At this time the innovative technology is available from the vendor only as a vendor-provided service, i.e., only as a leased service operated and staffed by NUKEM, with no purchase or rental options.

Each time the Copper Cable Recycling Technology is shut down and restarted, approximately 2 hours is required to balance the air movers at the beginning of the day and to allow the copper to clean out of the system at the end of the day. This may very but needs to be considered each time the Copper Cable Recycling Technology is started and stopped. The Copper Cable Recycling Technology is more cost effective if it can run continuously for as long as possible to avoid the startup and shutdown procedures associated with balancing the air movers and removing the remaining copper from the system. Double shifts or around the clock operation should be considered for more cost-effective operation.

Technology Limitations and Needs for Future Development

The following should be considered to facilitate setup time and to provide each customer with a complete recycle unit.

- Convert all motors on the recycle unit to US standards i.e.: change form 50Hz.to 60Hz. This would allow operation of the recycle unit using US commercial power.
- Provide HEPA filter systems with the recycle unit
- Consider designing the unit as one piece and thus reducing setup time and cost associated with using a crane for setup.
- Provide power hookup cable with the system.
- Provide all exhaust and dust collection equipment

Technology Selection Considerations

Based on the INEEL demonstration, the innovative technology is better suited for large recycle projects, greater than 25,000 lbs. There are instances where the baseline technology would be preferable and this would need to be considered based on disposal costs and the level of effort required for preparing the cable for recycling.

APPENDIX A

REFERENCES

Idaho National Engineering and Environmental Laboratory, Technology Opportunity Statement Summary ID # ID-7.2.23, Need Title-Copper Wire Recycle

APPENDIX B
COST COMPARISON DETAILS

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work. In the estimate, the activities are grouped under higher level work titles per the work breakdown structure shown in the ***Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*** (HTRW RA WBS) (USACE 1996). The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with the established national standards.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- The NUKEM Copper Cable Recycling Technology is currently offered only as a vendor-provided service. The rate used in this cost analysis is based on a quote from the vendor of $14,500 per day and the observed workday length (average) of 8-1/2 hours ($1,705.88/hr).
- INEEL provided support for the innovative technology in the form of a forklift, generator, truck and crane. The equipment rates and equipment operator rate is based on standard rates for INEEL.
- The HEPA filter unit was rented. The rate used in the cost analysis of $13.01 is based on the unit's rental rate amount plus the cost of the filter amortized over the period of operation (rental rate $5.29/hr each HEPA filter plus $7.81/hr ($250 each filter for 32 hours of operation = $7.81/hr)).
- The standard labor rates established by the Idaho National Engineering and Environmental Laboratory (INEEL) are used in this estimate and include salary, fringe, departmental overhead, material handling markups, and facility service center markups.
- The equipment rates and the labor rates do not include the Bechtel BWXT Idaho, LLC in general and administrative (G&A) markups. The G&A are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. The G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision-makers seeking site-specific costs can apply their site’s rates to this analysis without having to first back out the rates used at the INEEL.

The analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation costs.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity is described in this section.

Mobilization (WBS 331.01)

Air fare, round-trip: This item is the innovative technology cost for round trip air fare between South Carolina and Idaho for four process engineers.

Per-diem: Included in this line item is per-diem allowance for four NUKEM process operators for one week, for the innovative technology. Per-diem rates are per the U.S. General Services Administration.

Car rental: Included in the costs for the innovative technology is the rental of one car for the period of the demonstration, one contiguous week.

Shipping and handling, round-trip: This item concerns the innovative technology. NUKEM has indicated that the round-trip cost for shipping the NUKEM Copper Cable Recycling Technology from South Carolina to Idaho is $9,000, and that it allows four hours loading and unloading time (demurrage) per round-trip shipment (i.e., two hours at each end of the trip). This cost analysis includes costs for INEEL labor and equipment supporting the loading and unloading. The site support includes one crane, one crane operator, one forklift, and one forklift operator are included in the costs for this line item.

HEPA filter setup: The HEPA filter setup during the demonstration required several days of effort. The duration for this was longer than a normal job because of miscommunications about the HEPA filter requirements and difficulties locating an acceptable unit. Based on the test engineer's judgment, a reasonable time to allow for the HEPA filter setup is 4 hours.

Electrical hookup: The hookup to power required several hours in the demonstration. Problems with locating an acceptable power cable caused delays that are not representative of future work. Based on the test engineer's judgment, a reasonable time to allow for the electrical hookup is 1 hour.

Unpack and setup: Uncrating of equipment, connecting the components together and general setup is approximately 1-1/2 days of effort for the NUKEM equipment.

D&D Work (WBS 331.17)

Meetings and Don Personal Protective Equipment (PPE): This activity includes the labor time spent in the pre-job safety meeting each morning and includes standby time for the NUKEM Copper Cable Recycling Technology. Additionally, the labor and material cost for donning the articles of clothing listed in table B-1. The duration of the donning and the number of donning events are based on observations of the demonstration.

Table B-1 Cost for PPE (per man/day)

Equipment	**Cost Each**	**Number of Times Used Before Discarded**	**Cost Each Time Used ($)**	**No. Used Per Day**	**Cost Per Day ($)**
Rubber overboots (pvc yellow 1/16 in thick)	$12.15	30	$0.41	1	$0.41
Glove liners pr. (cotton inner)	$0.40	1	$0.40	2	$0.80
Rubber Gloves pr. (outer)	$1.20	1	$1.20	2	$2.40
Tyvek	$3.30	1	$3.30	1	$3.30
Respirator (full face)	$222	50	$4.44	1	$4.44
Cartridges	$7.51	1	$7.51	2	$15.02
TOTAL COST/DAY/PERSON					**$25.96**

Processing: This includes processing of cable by the NUKEM machine. Cables are segmented and placed on a conveyor that feeds into the pre-shredder. The pre-shredder reduces the cable into lengths that can be most efficiently processed by the grinder. The activity includes periodic emptying of dust collection bags and the bins used to capture copper and insulation granules. The NUKEM operators are supported by a site forklift and laborer who operates the forklift and helps segment the cable. Production rate for the innovative technology is based on a total operation time of 32 hours processing 27,100 pounds of copper cable (847 lb./hr).

Sales: This cost element assumes that INEEL sells the scrap copper when the NUKEM processing is completed. The income from the sale offsets some of the costs. The rate for salvage copper used in Table B-2 is based on the national average rate for salvage copper.

Sample Analysis: There were two types of analysis performed for the innovative technology, cobalt by inductively coupled plasma, and cesium nitrate via atomic absorption. This would be typical for a field characterization scenario. Different types of analyses may be associated with other scenarios such as field screening or confirmatory sampling. The sample analysis costs observed for this demonstration are used in the cost analysis.

Demobilization (WBS 331.21)

Decontaminate: Based on the test engineer's judgment, two days of effort are assumed in this cost analysis for decontamination of the NUKEM equipment prior to release from the INEEL.

Ship and Handle - Round Trip: See mobilization task.

Disposal (WBS 331.18)

Transport and Unload: The activity includes loading the waste onto a truck, transport to the disposal area, and unloading. The quantity of waste for the innovative technology is 4 boxes of dust and 5 boxes of insulation. The baseline technology has 21 boxes of waste for disposal. The truck capacity is 12 disposal boxes per trip and would require 1 trip for the innovative technology waste and 2 trips for the baseline technology waste. The time required is 1 hour to load, 1/2 hour to transport, and 1 hour to unload for each trip.

Disposal of Dust and Insulation Materials: The quantity of waste for the innovative technology is 4 boxes of dust and 5 boxes of insulation. The insulation material can be used as void filler material for waste disposal on other projects and is not included the costs for disposal for the innovative technology. Only the 4 boxes of dust are included in the cost analysis. The baseline technology has 21 boxes of waste for disposal. The cost for the box material and labor for constructing the boxes is included in the analysis and standard rates used at INEEL are $600/box. The disposal fee $9,600/box (2'x4'x8' box at $150/cf) plus the cost of the box ($600/box) give a total cost of $10,200 per box.

Disposal of PPE Waste: This cost analysis assumes 1 cf of PPE waste for the workers loading the waste for the baseline technology. The three operators of the NUKEM equipment plus the forklift operator are assumed to generate 2 cf of PPE waste each day of operation.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration and all production rates so that site specific differences in these items can be identified and a site specific cost estimate may be developed.

Table B-2. Baseline Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost							Comments
					Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	
Facility Deactivation, Decommissioning, & Dismantlement								**Total Cost =**				**$ 215,566.60**
Disposal (WBS 331.18)										Subtotal =		$ 215,566.60
Transport & Unload	ls	608.30	2	$ 1,216.60		5.00	TD, LB, FO	105.86	FT, FL	15.80		
Disposal of Cable	box	10,200.00	21	$ 214,200.00							10,200	Box $600 ea+fee of $150/c
Disposal PPE	cf	150.00	1	$ 150.00							150	Disposal fee = $150/cf

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-eation	Crew Item	Rate $/hr	Abbreveation	Equipment Item	Rate $/hr	Abbrev-eation	Equipment Item	Rate $/hr	Abbrev-eation
Heavy Equipment Op	38.65	HO	Laborer	32.86	LB	Forklift	3.30	FL	Flatbed Truck	12.50	FT
Forklift Operator	38.65	FO	Driver	34.35	TD						

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ls = lump sum; ea = each; and, loc = location; ft^3 = cubic feet.
3. Other abbreviations: PPE = personal protective equipment

Table B-2. Innovative Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
Facility Deactivation, Decommissioning, & Dismantlement							**Total Cost =**					**$ 183.464.5**
Mobilization (WBS 331.01)										Subtotal =		$ 47,199.9
Air Fare - Round Trip	ea	1,913.00	4	$ 7,652.00								4 process operators
Per Diem	wk	495.00	4	$ 1,980.00								4 process operators
Car Rental	ea	42.00	1	$ 42.00								
Ship & Handl - Round Trip	ea	4,666.30	1	$ 4,666.30		2.00	HO, FL	77.30	CN, FL	5.85	4,500	$4,500 for shipping
HEPA Filter Setup	ea	6,875.56	1	$ 6,875.56		4.00			NK, HF	1718.89		
Electrical Hookup	ea	1,743.53	1	$ 1,743.53		1.00	EL	37.65	NK	1705.88		
Unpack & Setup	ea	20,470.56	1	$ 20,470.56		12.00			NK	1705.88		
INEEL Procurement Cost	ls	3,770.00	1	$ 3,770.00								5.2% of total vendor cost
D&D Work (WBS 331.17)										Subtotal =		$ 60,498.7
Meetings & Don PPE	ea	543.23	5	$ 2,716.13		0.25	FO	38.65	NK,HF (stand by)	1718.89	104	PPE $25.96 ea for 4 perso
Processing	lb	2.09	27,100	$ 56,589.41	847 lbs/hr		FO	38.65	NK , FL, GN, HF	1730.03		Production rate 847 lb/hr
Sales	lb	-0.80	17,275	$ (13,820.00)								$0.80/lb assumed
Doff PPE	ea	436.13	5.0	$ 2,180.66		0.25	FO	38.65	NK (stand by)	1705.88		
Lab Analysis - Samples	ea	90.37	142	$ 12,832.54								
Demobilization (WBS 331.21)										Subtotal =		$ 33,266.6
Decontaminate	ea	28,600.32	1.0	$ 28,600.32		16.00	RCT, LB	68.63	NK, HF (stand by)	1718.89		
Ship & Handl - Round Trip	ea	4,666.30	1	$ 4,666.30		2.00	HO, FL	77.30	CN, FL	5.85	4,500	
Disposal (WBS 331.18)										Subtotal =		$ 42,499.2
Transport & Unload	ls	199.28	1	$ 199.28		2.50	TD, LB	67.21	FT	12.50		
Disposal Insulation & Dus	box	10,200.00	4	$ 40,800.00							10,200	Box $600 ea+fee of $150/
Disposal PPE	cf	150.00	10	$ 1,500.00							150	Disposal fee = $150/cf

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-eation	Crew Item	Rate $/hr	Abbreveation	Equipment Item	Rate $/hr	Abbrev-eation	Equipment Item	Rate $/hr	Abbrev eation
Heavy Equipment Op	38.65	HO	Laborer	32.86	LB	Forklift	3.30	FL	Flatbed Truck	12.50	FT
Forklift Operator/Laborer	38.65	FO	Driver	34.35	TD	Crane-Trackmobile	2.55	CN	HEPA Filter Rental	13.01	HF
Radiation Control Tech	35.77	RCT				Generator	7.84	GN			
Electrician	37.65	EL				NUKEM Copper Recycle	1705.88	NK			

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ls = lump sum; ea = each; and, loc = location; ft^3 = cubic feet.
3. Other abbreviations: PPE = personal protective equipment

APPENDIX C
ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
CF	Central Facility
D&D	Deactivation and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DOE	United States Department of Energy
DB	Decibel
G&A	General and Administrative
HEPA	High Efficiency Particulate Air
INEEL	Idaho National Engineering and Environmental Laboratory
LLW	Low-Level Waste
LSDDP	Large Scale Demonstration and Deployment Project
NETL	National Energy Technology Laboratory
OMB	Office of Management and Budget
OST	Office of Science and Technology
JSA	Job Safety Analysis
PPE	Personal Protective Equipment
RCT	Radiation Control Technician
TWA	Time Weighted Average
WBS	Work Breakdown Structure